

CLAIMS

1. A device for ablating the stratum corneum epidermidis of a subject, comprising:
a plurality of electrodes, which are applied to the subject's skin at respective points; and
a power source, which applies electrical energy between two or more of the plurality of electrodes, to cause ablation of the stratum corneum primarily in an area intermediate the respective points.
2. A device according to claim 1, wherein skin layers beneath the stratum corneum are substantially not ablated.
3. A device according to claim 1, wherein the ablation of the stratum corneum causes a puncturing thereof.
4. A device according to claim 1, wherein the device ablates the area of the stratum corneum in order to allow a substance to pass therethrough.
5. A device according to claim 4, wherein the substance comprises a drug that is delivered through the skin.
6. A device according to claim 4, wherein the substance comprises an analyte that is extracted through the skin.
7. A device according to claim 1, wherein the power source generates an electric field which causes a current to flow through the stratum corneum, and wherein the device reduces power dissipated in the stratum corneum responsive to variation of a characteristic of the current.
8. A device according to claim 7, wherein the characteristic is drawn from a list consisting of: the magnitude of the current; a time-integration of the current; a first time-derivative of the current; and a second time-derivative of the current.
9. A device according to claim 7, wherein current

through one of the plurality of electrodes is reduced substantially independently of the current through another one of the plurality of electrodes.

10. A device according to claim 7, wherein at least one of the plurality of electrodes is coupled to receive the current through a limited-conduction unit, which unit allows current below a threshold value to flow therethrough substantially unimpeded, and becomes substantially non-conductive if the current flowing therethrough exceeds a limited-conduction threshold value.

11. A device according to claim 7, wherein at least one of the plurality of electrodes is coupled to an electrically-conductive dissolving element characterized by a dissolving rate generally proportional to the current passing therethrough, which becomes substantially nonconductive responsive to a function of the current.

12. A device according to claim 11, wherein the function comprises a time-integral of the current having passed through the dissolving element.

13. A device according to claim 11, wherein the dissolving element comprises:

an electrolyte solution within the element; and
a first node and a common node immersed in the electrolyte solution,

wherein current flows from the first node to the common node through the electrolyte solution, the current flow causing the common node to be consumed at a rate generally proportional to the current passing therethrough, such that the dissolving element becomes substantially nonconductive when the total charge having passed through the common node exceeds a common node threshold value.

14. A device according to claim 13, wherein the

dissolving element further comprises a second node, immersed in the electrolyte solution, wherein the power source generates alternating current, and wherein the device further comprises:

- a first diode, coupled in series between the power source and the first node, which conducts current from the power source to the first node when the alternating current is in a positive phase thereof; and

- a second diode, coupled in series between the power source and the second node, which conducts current from the second node to the power source when the alternating current is in a negative phase thereof,

- such that the dissolving element becomes substantially nonconductive when the total charge having passed through the common node exceeds a common node threshold value.

15. A device according to claim 11, wherein the dissolving element comprises:

- an electrolyte solution within the element;

- a large-area anode immersed in the electrolyte solution; and

- a plurality of cathodes, immersed in the electrolyte solution, each of the cathodes being coupled to a respective one of the plurality of electrodes,

- wherein current flows from the large-area anode to the plurality of cathodes through the electrolyte solution, the current flow causing at least one of the cathodes to be consumed at a rate generally proportional to the current passing therethrough, and wherein the at least one cathode becomes substantially nonconductive responsive to a function of the current having passed therethrough.

16. A device according to claim 7, wherein the current through at least one of the plurality of electrodes is reduced responsive to the variation of the characteristic

of the current through another one of the plurality of electrodes.

17. A device according to claim 7, and comprising a voltage sensing unit coupled to measure a voltage drop across two of the plurality of electrodes, and wherein current from the power source is reduced responsive to the measurement made by the sensing unit.

18. A device according to claim 17, wherein the power source comprises a current source, and wherein current from the current source is reduced responsive to a measurement made by the sensing unit which indicates that the electrical potential between the two electrodes is below a voltage-threshold value.

19. A device according to claim 17, and comprising a resistive element coupled to one of the two electrodes and to the power source, wherein the voltage sensing unit is further coupled to measure a voltage drop across the resistive element in order to determine a current passing therethrough, wherein the power source comprises an alternating current source, such that the measurements of the voltage drop across the two electrodes and the current through the resistive element determine a phase shift, and wherein the current from the alternating current source is reduced responsive to the phase shift being below a threshold value.

20. A device according to claim 7, and comprising:

- a resistive element coupled to one of the plurality of electrodes and to the power source; and

- a voltage sensing unit coupled to measure a voltage drop across the resistive element in order to determine a current passing therethrough,

- wherein the power source comprises a voltage source, and wherein a voltage of the source is reduced responsive to a measurement made by the sensing unit which indicates that the current through the resistive element is above a

current-threshold value.

21. A device according to claim 7, wherein at least one of the plurality of electrodes is printed directly on the skin and becomes substantially electrically nonconductive responsive to the value of the current passing therethrough being greater than a threshold value.

22. A device according to claim 7, and comprising:

a capacitor, coupled to two of the plurality of electrodes; and

a switch, coupled to the power source and the capacitor, such that the switch, in a closed phase thereof, allows current to flow from the power source to the capacitor and to the two electrodes, and such that the switch, in an open phase thereof, substantially terminates current flow from the power source to the capacitor and to the two electrodes,

wherein the power source charges the capacitor during the closed phase, and wherein the capacitor discharges current through the electrodes during the open phase.

23. A device according to claim 1, wherein the distance between two of the plurality of electrodes is less than about 0.3 mm.

24. A device according to claim 23, wherein the distance between two of the plurality of electrodes is between about 0.01 mm and about 0.1 mm.

25. A device according to claim 1, wherein the plurality of electrodes comprise:

a common electrode, which has a plurality of perforations therethrough; and

a plurality of positive electrodes, each positive electrode passing through a respective perforation of the common electrode,

such that current from the power source flows from

each positive electrode through the skin to the common electrode.

26. A device according to claim 1, wherein the power source generates alternating current, a frequency thereof being above about 100 Hz.

27. A device according to claim 26, wherein the frequency is between about 1 kHz and about 300 kHz.

28. A device according to claim 1, wherein the power source generates alternating current and modulates a frequency thereof between a first frequency value and a second frequency value.

29. A device for passing electrical current through the skin of a subject, comprising:

- a power source, which generates the current;
- a plurality of electrodes, which are applied to the skin at respective points; and

- an electrically conductive dissolving element coupled to at least one of the electrodes, the element being characterized by a dissolving rate generally proportional to the current passing therethrough, and becoming substantially nonconductive responsive to a function of the current passing therethrough.

30. A method for ablating the stratum corneum epidermidis of a subject, comprising:

- placing a plurality of electrodes against the subject's skin at respective points; and

- applying electrical energy between two or more of the plurality of electrodes, in order to cause ablation of the stratum corneum primarily in an area intermediate the respective points.

31. A method according to claim 30, wherein skin layers beneath the stratum corneum are substantially not ablated.

32. A method according to claim 30, wherein applying the electrical energy comprises puncturing the skin.
33. A method according to claim 30, wherein applying the energy comprises ablating the area of the stratum corneum in order to allow a substance to pass through the area.
34. A method according to claim 33, and comprising delivering a drug through the area.
35. A method according to claim 33, and comprising extracting an analyte through the area.
36. A method according to claim 30, wherein applying electrical energy comprises:
- causing a current to flow through the points on the skin; and
 - substantially reducing the current flow through the skin responsive to variation of a characteristic of the current.
37. A method according to claim 36, wherein the characteristic is drawn from a list consisting of: a magnitude of the current; a time-integration of the current; a first time-derivative of the current; and a second time-derivative of the current.
38. A method according to claim 36, wherein causing the current to flow comprises passing current to the one or more points on the skin through one or more respective limited-conduction units, wherein the units allow current below a threshold value to flow therethrough substantially unimpeded, and wherein the units become substantially nonconductive if the current flowing therethrough exceeds a limited-conduction threshold value.
39. A method according to claim 36, wherein causing the current to flow comprises passing current to the one or more points on the skin through one or more respective electrically conductive dissolving elements, each element

characterized by a dissolving rate generally proportional to the current passing therethrough, and becoming substantially nonconductive when the total charge having passed therethrough exceeds a dissolving element threshold value.

40. A method according to claim 36, wherein reducing the current flow comprises reducing the current at one of the respective points substantially independently of the current at another one of the respective points.

41. A method according to claim 36, wherein reducing current flow comprises:

monitoring the current flow through one of the plurality of electrodes; and

reducing the current flow through another one of the plurality of electrodes responsive thereto.

42. A method according to claim 30, wherein applying electrical energy comprises generating alternating current, a frequency thereof being above about 100 Hz.

43. A method according to claim 42, wherein the frequency is between about 1 kHz and about 300 kHz.

44. A method according to claim 30, wherein applying electrical energy comprises generating alternating current and modulating a frequency thereof between a first frequency value and a second frequency value.

45. A method according to claim 30, wherein placing the plurality of electrodes comprises placing two of the plurality of electrodes at a separation therebetween that is less than about 0.3 mm.

46. A method according to claim 45, wherein placing the plurality of electrodes comprises placing the two of the plurality of electrodes at a separation between about 0.01 mm and about 0.1 mm.

47. A method according to claim 30, wherein placing the

plurality of electrodes comprises:

applying a conduction-enhancing material to an area on the surface of the subject's skin in order to enhance current flow through the skin; and

placing the electrodes on the material,

wherein the electrical resistance of the conduction-enhancing material increases responsive to a function of the current flow therethrough.

48. A method according to claim 30, wherein placing the plurality of electrodes comprises:

placing on the skin a common electrode which has a plurality of perforations therethrough; and

placing on the skin a plurality of positive electrodes, each positive electrode passing through a respective perforation in the common electrode,

such that current from the power source flows from each positive electrode through the skin to the common electrode.

49. A method according to claim 30, and comprising positioning in a vicinity of the electrodes a medical patch containing the substance, such that ablation of the stratum corneum increases a transport rate of the substance from the patch into the skin.

50. A method for passing electrical current through the skin of a subject, comprising:

placing a plurality of electrodes against the skin at respective points;

applying the current through the electrodes; and

coupling to at least one of the electrodes an electrically conductive dissolving element, the element being characterized by having a dissolving rate generally proportional to the current passing therethrough, and by becoming substantially nonconductive responsive to a function of the current passing therethrough.